PO-0783

Dosimetric influence of pitch for radiotherapy of long treatment volumes

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Purpose/Objective: Pitch usually has little impact on the dose distribution for radiation of small spherical treatment volumes such as brain metastases or prostates. However, for geometrical reasons a pitch might be detrimental for patients with long treatment volumes, such as nasopharyngeal carcinoma (NPC) or esophageal cancer. During the course of radiotherapy patients with head and neck cancer may have rotational variations of up to 8° and esophageal cancer patients of up to 6° (Zhang L et al. Int J Radiat Oncol Biol Phys 2006, Chen YL et al. Int J Radiat Oncol Biol Phys 2007). The purpose of our study was to investigate if the dose distribution in the case of long treatment volumes is relevantly affected by the patient's pitch and if a correction using a treatment couch with six degrees of freedom (6DoF) is necessary.

Materials and Methods: 10 patients with NPC and 10 patients with esophageal cancer have been included in our planning study. All patients have been treated with volumetric modulated arc therapy (VMAT) with 66-70 Gy in 33-35 fractions in the case of NPC and with 41.4-54 Gy in 23-28 fractions in the case of esophageal cancer. Patient's pitch was simulated by tilting the planning CT in ventral and dorsal direction by +/-1.5° and +/-3° around the middle of the dens axis for NPC volumes and the middle of the PTV for esophageal volumes. These rotational values were chosen, because most clinical treatment tables with 6 DoF are not able to adjust a tilt of more than 3°. A copy of the original CT dataset was made, identifying DICOM tags were deleted and PTV structures and structures of OARs were copied on the CT dataset. Verification plans were calculated on the four tilted datasets. PTV coverage and mean and maximum dose to the organs at risk (OARs) were compared to the original plan and to the dose constraints of the OARs.

Results: For NPC patients the deviation in dose to the PTV is increasing with the degree of pitch but the effect appears to be relatively small with mean changes of up to 2%. For esophageal cancer pitches of 1.5° and 3° resulted in even less variation of dose to the PTV and PTV coverage with mean changes of up to 1%. The OARs that are most affected by a certain tilt of NPC patients are brainstem, spinal cord, lenses, oral mucosa and parotid glands (see Table 1). Brain, chiasm and optical nerves were stable in absolute dose. For esophageal cancer there was no significant change in dose to any OAR and none of the OARs exceeded the organ tolerance due to the pitch. However, in NPC patients 11/40 treatment plans would no longer be acceptable according to the dose constraints of the OARs with a pitch of +/-1.5° (N=1/N=2) and +/-3° (N=3/N=5).

Table 1: Dose deviations for organs at risk in nasopharyngeal carcinoma patients dependent on degree and direction of the patient pitch. Standard deviations are shown in brackets.

	Pitch Nasopharyngeal Carcinoma [%]			
	3° ventral	1.5° ventral	1.5° dorsal	3° dorsal
Chiasm max	n.s.	n.s.	n.s.	n.s.
Chiasm mean	n.s.	n.s.	n.s.	n.s.
Brain mean	n.s.	n.s.	n.s.	n.s.
Brainstem max	-3.7 (3.3); p=0.013	-1.7 (1.9) 0.037	2.9 (3.1) 0.022	6.0 (6.3); p=0.017
Brainstem mean	-2.4 (4.0); p=0.028	n.s.	1.3 (2.3) 0.047	3.0 (5.5); p=0.037
Lens max (i)	3.3 (3.0); p=0.028	2.5 (2.5) 0.017	n.s.	-2.3 (2.9); p=0.037
Lens max (c)	3.2 (3.3); p=0.037	n.s.	n.s.	n.s.
Spinal cord max	-3.9 (5.2); p=0.028	-2.2 (3.0); p=0.047	5.1 (4.2); p=0.017	10.0 (9.9); p=0.013
Spinal cord mean	n.s.	-0.6 (0.6); p=0.013	1.9 (3.5); p=0.013	3.1 (4.1); p=0.013
Oral mucosa mean	2.6 (2.5); p=0.022	n.s.	-1.6 (1.3); p=0.013	-2.8 (3.0); p=0.017
Parotid gland mean (i)	4.3 (4.3); p=0.017	2.0 (2.2); p=0.022	-1.0 (1.6); p=0.047	-3.0 (3.1); p=0.014
Parotid gland mean (c)	4.1 (3.8); p=0.007	1.8 (1.7); p=0.013	-2.3 (2.1); p=0.009	-3.1 (3.2); p=0.013
Optical nerve max (i)	n.s.	n.s.	n.s.	n.s.
Optical nerve max (c)	n.s.	n.s.	-3.5 (3.8); p=0.047	n.s.

i: ipsilateral, c: contralateral, n.s.: not significant

Conclusions: PTV coverage in both tumor entities was only slightly affected, but pitch error could be detrimental for OARs in NPC patients. Therefore a correction is recommended for NPC patients, even with a pitch mismatch of 1.5°. In the latter situation the use of a 6DoF table might be clinically relevant.

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Rectal tumor volume shrinkage evaluated with MRI during preoperative chemoradiotherapy

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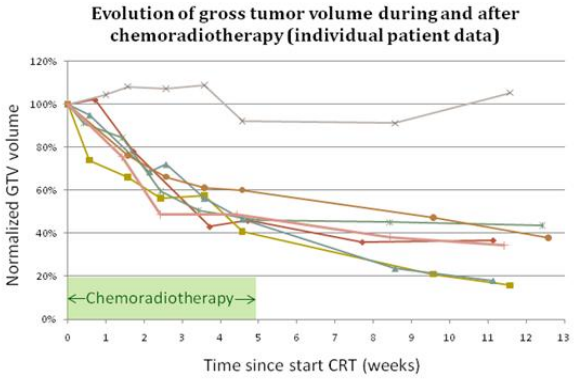
Purpose/Objective: Neoadjuvant chemoradiotherapy (CRT) decreases the local recurrence rate in patients with locally advanced rectal cancer. To enhance response, multiple centers are investigating the possibility of a boost dose to the gross tumor volume (GTV), either sequentially or simultaneously. Few data is available on GTV regression during CRT. We aim to determine the pattern in order to optimize timing of dose escalation on the GTV and assess possibilities for adaptive planning.

Materials and Methods: MRI was obtained before, weekly during, and 4 and 7 weeks after a five-week course of concomitant CRT in seven patients with locally advanced rectal cancer (T3-4 and/or N1-2). A dose of 50 Gy was administered during CRT, combined with daily capecitabine. GTV was contoured on high resolution axial T2 images, aided by diffusion weighted imaging (DWI) and the apparent diffusion coefficient map (ADC). Planning target volumes (PTV) were created on each time point, with margins based on previous research: 10 mm anteroposteriorly, 6 mm laterally and 12 mm craniocaudally.

Results: On the whole, 52 usable MRIs were acquired. GTV volume measured 63.3 cc (SD 20.5 cc) at baseline and PTV 209 cc (SD 50 cc). In six patients, tumor shrinkage started in the first two weeks of CRT, amounting to an average reduction of 10% per week (fig. 1). The seventh patient showed no response during CRT and suffered local progression before planned surgery.

Overall, mean GTV volume after CRT was 32.3 cc (± 9.3 cc), a reduction of 45.7 % (± 17.7 %, p=0.018). The PTV volume after CRT was reduced by 72 cc ± 31 cc (34 % ± 12 %, p=0.018). Further reduction occurred up to seven weeks post-CRT, resulting in mean GTV volume of 22.3 cc (± 9.3 cc), showing a total reduction of 58.3% (± 30.0%, p=0.028) compared to baseline.



Conclusions: GTV shrinkage of rectal tumors treated with neoadjuvant chemoradiotherapy already occurs in the first two weeks of treatment and continues up to 7 weeks post-treatment. The observed volume reduction during treatment suggests a benefit for a sequential boost on the remaining tumor after CRT or for volume adaptation in case of a simultaneous integrated boost.

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Inverse planning of beam-on times for precision image-guided 3D small animal radiotherapy treatments

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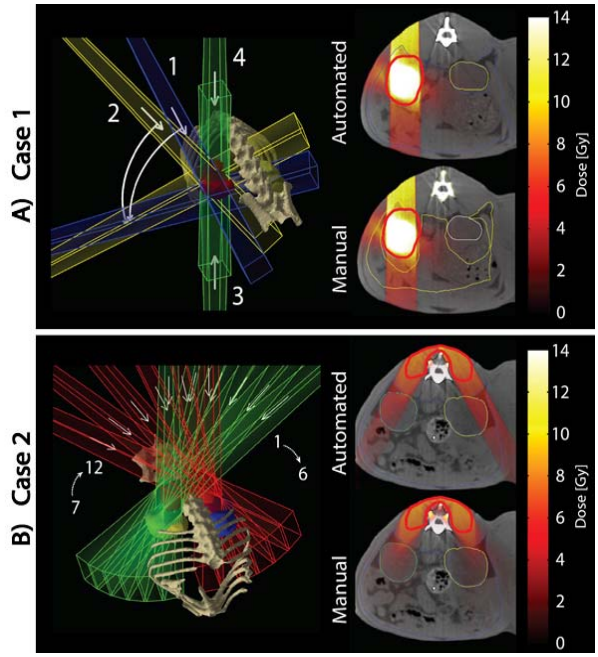
Purpose/Objective: Advances in small animal radiotherapy enable the delivery of increasingly complex heterogeneous dose distributions on the millimeter scale, but methods to plan complicated small animal treatments remain in their infancy. A pre-clinical irradiation plan is usually created based on cone beam CT data with the animal in treatment position under anesthesia. Combined with demands on throughput, fast and easy treatment planning methods and algorithms are required. The purpose of this study is to develop an optimization model that determines beam-on times for a given beam configuration, and to assess the benefits of automated treatment planning for small animal radiotherapy.

Materials and Methods: The applied model determines a Pareto-optimal solution based on user-provided weights for objectives. An interactive approach allows the user to select the plan that yields the most preferred trade-offs. Two cases based on cone beam CT data of a rat were used, and manual and model-based optimization results were compared using dose-volume metrics. The kidneys, spine and gastrointestinal tract (GI) were delineated as organs at risk (OARs) and a fictitious planning target volume (PTV) was created around the spine. In case 1, the left kidney was targeted as PTV with four 10x10 mm^2 beams and for case 2, twelve 8x10 mm^2 beams were used to target the PTV around the spine. A PTV dose of 8 Gy was prescribed, with a mean dose between 8 and 10 Gy as constraint. Differences between prescribed and planned PTV dose, as well as OAR doses were included in penalty objectives. The model was integrated in a research version of Monte Carlo based small animal treatment planning system SmART-Plan (v2.0 Precision X-ray).

Results: Results show that manual and automated treatment planning yields plans of similar quality as shown in the figure and table. A similar amount of time was needed for manual and model-based optimization. In this period, manual optimization generates a single plan, while a set of Pareto-optimal plans is created with automated optimization, allowing for a more substantiated choice on trade-offs. Automated optimization often uses fewer beams than manual optimized plans, therewith lowering treatment delivery time. Additional benefits of automated planning include a decreased dependence on the planning skills of the user (often absent in pre-clinical research), and the potential to improve treatment standardization among institutions. For more complex irradiations, manual planning becomes infeasible, making automation a necessity.



		Case 1		Case 2	
		Man	Aut	Man	Aut
PTV	$V_{95\%}$ (%)	61.2	61.7	83.8	84.3
	$D_{95\%}$ (Gy)	1.1	0.5	5.9	5.4
	D_{mean} (Gy)	8.3	8.2	8.3	8.1
	$D_{5\%}$ (Gy)	13.8	15.6	9.6	9.4
Left kidney	$D_{95\%}$ (Gy)	n.a.	n.a.	0.2	0.2
	$D_{5\%}$ (Gy)	n.a.	n.a.	5.5	6.1
GI	$D_{95\%}$ (Gy)	0.1	0.0	0.1	0.1
	$D_{5\%}$ (Gy)	6.9	5.9	2.4	4.4
Right kidney	$D_{95\%}$ (Gy)	0.2	0.1	0.3	0.2
	$D_{5\%}$ (Gy)	1.6	1.8	4.7	6.1
Spine	$D_{95\%}$ (Gy)	0.0	0.0	0.1	0.1
	$D_{5\%}$ (Gy)	0.3	0.3	7.4	3.0

Conclusions: Automation of treatment planning offers benefits to optimize plan quality in the short available time for treatment planning, to decrease dependence on user skills, to give more insight in trade-offs, and to improve standardization. The interactive Pareto-optimization framework was be able to produce plans of good quality, and allows for extension to full inverse treatment planning.